June, 1913 Botanical Series. Vol. VI, No. 1.

Memoirs of the Department of Agriculture in India

NOTES ON POLLINATION AND CROSS-FERTILISATION IN THE COMMON RICE PLANT ORYZA SATIVA, LINN

BY

G. P. HECTOR, M.A., B.SC

Economic Botanist, Bengal

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

THACKER, SPINK & CO., CALCUTTA

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Price, Re. 1.

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

BOTANICAL SERIES

VOL. VI

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PUBLISHED FOR
THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY
THACKER, SPINK & CO., CALCUTTA
W. THACKER & CO., 2, CREED LANE, LONDON

CALCUTTA :

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I.—Introductory.

During the past two years a large number of varieties of rice, cultivated in the districts of Lower Bengal, have been grown on the Dacca farm, with the object of studying their characters in single plant cultures and of ascertaining to what extent, if any, natural cross-fertilisation takes place, as a correct estimation of this latter point and of the precautions likely to be necessary to keep varieties pure, is an essential preliminary to the work of successfully distributing seed of improved types. This preliminary work is necessary in the case of all crops, but particularly so in the case of a crop like rice, in which the number of cultivated varieties, differing frequently by most minute points of difference, is very large, and the risk of accidental mixture of seed very great, owing to the peculiar conditions under which rice is grown.

Though the results obtained up to date are far from complete, they have shown that while some types are much superior to others and self-fertilisation is the normal process, cross-fertilisation does undoubtedly take place and under certain circumstances may considerably affect the successful introduction of an improved type into any particular locality where other inferior types are commonly grown. This question of pollination and

cross-fertilisation in rice has not been studied in detail in India, and in the following notes it is proposed to give a preliminary account of our observations on the subject, as far as the districts of Lower Bengal are concerned.

II.—Pollination.

A superficial examination of the flower of rice would lead one to believe that cross-pollination by the agency of the wind was the normal method. Shortly after the opening of the glumes the anthers may be seen hanging downwards from their filaments in such a way as almost to preclude the pollen from reaching the stigma of the same flower if dehiscence has not already taken place before this pendent position is reached, and frequently also the two feathery stigmas may be seen protruding one on either side from between the open glumes. Though no work has hitherto been done in India on the subject, much has been done in other countries, and a brief summary of previous literature is given below. Knuth* states that the species is allogamous and that the anthers are still closed when they emerge from the glumes, and do not dehisce till after they have bent over and hang downwards. More recently a Japanese worker, M. Akemine,† has given a detailed account of the morphology of the flower and of the flowering of a race of swamp-rice, known as "Akaghé," occurring in Northern Japan. Only a summary‡ of this paper has been seen by us. According to the summary, the author discusses in detail the climatic factors affecting the flowering and setting of the grain, describes the method of pollination, and gives cytological details regarding the fertilisation process. He gives no cases of the occurrence of cross-fertilisation, and concludes, from observations and experiments on the flower, that self-fertilisation is what usually occurs, pollination according to the writer taking place just before the flowers open. Lastly, Fruwirth and Van der

* Hand-book of Flower Pollination, Vol. III, 1909, p. 521.

† "On the Flowers and Flowering of O. sativa," Agric. Gazette, Nôgyô-Sekai, 1910-11.

‡ Cf. Bot. Centralblatt, No. 41 of 1911, pp. 370-71.

Stok* summarize fully all the work done up to date, chiefly by the latter in Java, on the subject of rice-breeding in general, including the question of pollination and cross-fertilisation. According to these authorities, self-fertilisation is the usual process, but cross-fertilisation may not infrequently take place between neighbouring plants, and must be taken account of in all breeding work.

According to our observations on the Dacca farm, the actual process of pollination is as follows :—

The spikelets, or flowers, mature from above downwards in a fairly regular sequence, and in the case of any individual flower the opening of the glumes and pollination takes place, as a rule, on the same day as that on which it emerges above the level of the leaf-sheath if this happens before mid-day, or at latest in the course of the forenoon of the following day. In almost every normal case, dehiscence of the anthers and pollination take place practically simultaneously with the opening of the glumes, sometimes even before they open at all, and at the time of dehiscence the stigmas are still enclosed and the anthers still within the shelter of the glumes. Hence self-fertilisation appears to be the usual method. In the case of *Aus* varieties, which in Lower Bengal flower during the months of May and June, the opening of the glumes and dehiscence of the anthers commences usually between the hours of 7 and 8 A.M. and continues till about 10 A.M. when it stops for the day, but in the case of the *Aman* varieties which generally begin to flower in late October or early November, not till later in the forenoon, beginning usually between 9 and 10 A.M., and continuing till mid-day. The later time of day at which the flowers of the *Aman* varieties open is probably due to the much lower temperatures in October and November.

Immediately before the flowers open and dehiscence takes place it may be seen that the top of the anthers is just touching the concave roof formed by the glumes which are still closed,

* Fruwirth, Die Züchtung der Landwirtschaftlichen Kulturpflanzen, B. V., 1912, pp. 36—54.

and if at this stage the glumes are gently pulled apart, the anthers may be seen to dehisce and the pollen to fall in showers on to the feathery stigmas within. It is probable that the pressure of the anthers—which at this stage are being pushed up by the rapidly elongating filaments from below—on the glumes, together with the slight shock caused by the opening of the glumes and the consequent access of air and sunlight, are the immediate causes which bring about dehiscence.

Immediately after dehiscence, the glumes diverge a little further apart, the filaments rapidly elongate till the anthers protrude about their own length above the tip of the glumes, and then bend slowly outwards and downwards so that the anthers ultimately assume a pendent position. But before this stage is reached, in every normal case the anthers have already lost almost all their pollen and pollination has taken place before they emerged at all.

Both the extent to which the flowers open and the length of time they remain open vary considerably, but we have not been able to discover any differences in varieties with regard to this. It appears to be largely due to atmospheric conditions at the time. In the warmer and moister months of May and June the flowers of the *Aus* varieties open earlier in the morning, but appear to open to a less extent, and to remain open a shorter time than in the case of *Aman* varieties which flower in the colder and drier months of October-November. According to our observations, the whole process from the time of the opening of the glumes and dehiscence of the anthers till the time when the latter assume the pendent position, occupies on an average only about fifteen minutes, in both *Aus* and *Aman* varieties, but in the case of *Aus* varieties the flowers seldom remain open for a longer period than half an hour in all, while in the case of *Aman* varieties they may remain open for periods varying from about an hour to an hour and a half. If the weather is wet and rainy at the time when the flowers should normally open, as is frequently the case when the *Aus* varieties flower, they may not open at all, or if they do, they often do not close again, and a large percentage of

such flowers set no grain. It is a matter of common observation that a far larger number of empty husks are to be found in the heads of *Aus* varieties than in *Aman* varieties, due probably to the wet weather which often occurs in Lower Bengal when the *Aus* rices commence to flower.

In about four days a whole inflorescence will ordinarily have been pollinated in the way described above.

III.—Cross-Fertilisation.

Though the above is the normal process, the method of pollination by no means precludes the possibility of cross-pollination taking place. It has been pointed out above that the stigmas are not infrequently to be seen protruding from between the open glumes, while the stamens have not lost all their pollen when they assume the hanging position, so that there is every possibility, should self-pollination have failed, of cross-pollination resulting, and we have collected evidence to prove that it is by no means unknown, and under favourable weather conditions, bright sunshine with a gentle breeze, possibly takes place to a greater extent than we have as yet been able to prove. It is practically certain, however, that such cross-pollination as does take place is confined to neighbouring plants in the same plot, and that the pollen of one plant seldom if ever succeeds in reaching the stigma of a plant more than a foot or two away.

In the following paragraphs an account is given of the evidence we have so far collected as to the extent to which cross-pollination has been found to occur.

In 1911 single plant cultures of 150 types of transplanted *Aman* varieties were grown at Dacca farm from single plants selected in the season 1910. No cases of splitting crosses were found in these, and all were passed as pure at harvest time, but in four plots a few variant plants were found. Subsequent examination, however, in the laboratory, of the seed of certain white-grained varieties, proved that in some, red-grained seeds were to be found which had escaped detection at harvest time, and possibly there were others which were not discovered. Six

such cases were found, and in each case as many red-grained seeds as could be picked out were sown and the seedlings transplanted separately in 1912, every precaution being taken to prevent accidental mixture. In three of the six plots the red seeds have given rise to a few white-grained plants, proving that these were heterozygous as regards seed colour.

To return to the variant plants mentioned above, seed of four of these, which it was suspected might be crosses, was carefully preserved, sown and transplanted separately in 1912, and all have given rise to a variety of types as described below :—

The first of these (labelled Ba 1), was found in a variety named Gobrabali, a coarse rice from Bakarganj, and differed from the type chiefly in having reddish-coloured awns. This in 1912 split into four types—

(1)	Red awns, two inner glumes at flowering time pale green with red tip, turning yellow when ripe, stigmas black ...	60
(2)	Red awns, inner glumes at flowering time dark green with red tip, turning mottled brown, stigmas black ...	13
(3)	White awns, inner glumes at flowering time pale green with no tip, turning yellow, stigmas white	19
(4)	White awns, inner glumes at flowering time dark green with no tip, turning brown, stigmas white	4

Ratio red awns to white awns, 3·17 : 1

The second (labelled R 20) was found in a variety named Ukulmadhu from Rajshahi. The parent plant had a small, fine grain, the two small outer glumes yellow, and the inner glumes yellow with brownish coloured apex. This in 1912 split into three main types—

(1)	Small outer glumes yellow, inner glumes at first green with reddish tip, turning yellow with reddish tip, stigmas purple	5 noted.
(2)	Ditto, but with stigmas white	5 „
(3)	Small outer glumes coloured reddish-brown, inner glumes at first reddish with no tip, turning black, stigmas white ...	2

The only obvious difference between types (1) and (2) in this case lay in the colour of the stigma which can be accurately determined only before pollination has taken place. Unfortunately

the plot was not examined in detail till after flowering was almost over, and the colour of the stigma could be determined in only a small number of plants.

The third and fourth examples will be treated together. These were red-grained plants picked from white-grained plots, the red-grained plants in both cases being otherwise almost indistinguishable from the remaining white-grained plants in the plots. The first of these (labelled M 1) was found in a variety named Aman paddy from Mymensing, and the second (labelled B 15) in a variety named Bankalam from Bogra. These both split in 1912 into red and white-grained plants, otherwise almost indistinguishable except for grain colour, in the proportions given below—

1. M1, red-grained, 1911	... 1912, red-grained	... 145	} ratio.	
	white-grained	... 55	} 2·6r. : 1w.	
2. B15, red-grained, 1911	... 1912, red-grained	... 132	} ratio.	
	white-grained	... 68	} 1·9r. : 1w.	

Besides these four cases, much further evidence has been afforded by a series of Dinajpur varieties started from single plants selected in 1911. The seed of these varieties was collected from Dinajpur, partly from cultivators and partly from the Bazaars, and all were very mixed. In 1911, eighty-six single plants were selected from these Dinajpur plots and these were sown and transplanted separately in 1912 and no fewer than seven, or a percentage of 8·15, have given rise to a mixture of types. These are described below in detail.

In the first (labelled D 28), the parent plant had the small outer glumes coloured reddish-brown, and the inner glumes yellow with a dark apex. This in 1912 split into the following four main types :—

(1) Outer glumes coloured reddish-brown, inner glumes at flowering time green with red tip, turning yellow with dark tip, stigmas black	2	noted.
(2) Ditto with stigmas white	6	„
(3) Taller, more robust plant, outer glumes coloured reddish-brown, inner glumes at flowering time reddish, turning black, stigmas black	2	
(4) Ditto with stigmas white	1	

As in the case of R 20 described above, here again it was too late to determine accurately the stigma colour in types (1) and (2), the only obvious point of difference between them, when the plot was examined, except in the cases noted.

In the second (labelled D 6), the parent plant had a red grain and in 1912 split into four main types, two with red and two with white grains, as noted below.

D 6—Red-grained, 1911.

(1) Reddish leaf-sheaths and stem above nodes, grain white ... 14.	(2) Ditto, grain amber ... 1.	(3) Green leaf-sheaths and stems, grain red of various shades ... 43	(4) Ditto, grain white ... 26.

In the third (labelled D 7), the parent was red-grained, and split into three main types, two with red grains and one with white, in the proportions given—

1. Glumes yellow, grain red 50
2. Glumes mottled brown, grain red 34
3. Glumes mottled brown, grain white 13

The remaining four Dinajpur examples are similar to those of M 1 and B 15 described above, *viz.*, red-grained parent plants splitting into red and white-grained offspring, almost indistinguishable except for the colour of the grain. The details of these four cases are as follows :—

Parent 1911.	Offspring 1912.		Ratio R. : W.
	Red-grained.	White-grained.	
D 17 Red-grained. ...	72	21	3·4 : 1
D 18 ,, ...	72	24	3 : 1
D 35 ,, ...	51	21	2·42 : 1
D 38 ,, ...	68	32	2·12 : 1

From a perusal of the above figures, together with those of M 1 and B 15 quoted above, it would seem that as regards colour of grain segregation is taking place in the simple Mendelian ratio of 3 : 1.* Cross-fertilisation experiments are in

* Cf. Van der Stok, l. c., p. 49.

progress with the object of verifying this and also of determining the mode of inheritance of certain other characters.

In addition to the examples described above of undoubted splitting crosses, stray variant plants have also been found in twelve of the 1912 pure line plots started from single plants selected in 1910, and in fifteen of the 1912 Dinajpur series started from single plants selected in 1911, amounting to about fifty in all. Some of these may prove to be accidental mixtures but some cannot be matched with any of our other types, and have all the appearance of being the F_1 generation of crosses which must have taken place within our area in 1911. Seed of all these is being preserved and will be sown in 1913 and the results noted.

From the above cases there is reason to believe that natural crossing in rice is more common than was at first supposed. Moreover, under the conditions in which rice is grown by the cultivator, whose varieties are never free from mixtures, it would probably take place to a considerably greater extent than in our area at Dacca. Even if it did not occur to any greater extent than the cases cited would indicate, it would be quite sufficient to account for the extraordinarily large number of types which are to be found, when one takes into consideration the extent and great antiquity of the cultivation. Certain facts also which have been brought to our notice lend further evidence to this belief. For example, a cultivator from the neighbourhood of Chandpur recently informed us that on his own land within the past twelve years the number of distinct types to be found in his fields has increased from eight or ten to almost a hundred, although he has imported no new varieties.

The main conclusions to be drawn from the above results are :—

1. That in Lower Bengal under favourable conditions cross-fertilisation may take place in rice to an extent which may be provisionally estimated at about 4 per cent.

2. That this cross-fertilisation takes place wholly through the agency of the wind and would seem to be effective only between flowers of adjacent plants to a radius of a few feet.

3. That as regards certain characters at least, *e.g.*, grain colour, segregation along Mendelian lines appears to take place.

4. That so long as seed of a variety is kept free from accidental mixture there is no risk of contamination from cross-fertilisation, but that if seed gets mixed, cross-fertilisation will undoubtedly take place between adjacent plants in a plot and to an extent sufficient in a few years' time to reduce a variety to a number of splitting types. Hence the imperative necessity of taking every precaution to keep seed of varieties free from accidental mixtures.

DACCA,
10*th January* 1913.

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